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KELLY AIR FORCE BASE MAINTENANCE HANGAR: PLANNING

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STRUCTURAL DIVISION

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FOREWORD

In the past decade, remarkable progress has been made in the construction of large span, single story structures. The engineer of today, equipped with the facility of modern techniques is faced with a variety of important and decisive factors in the selection of method of design, construction and the application of structural material. To evaluate a building project, one must have intimate knowledge of the natures of the problems involved and the scope of the work within the established limitations of the functional requirements. It is intended, in this three-paper symposium, to bring out the interesting features and kindred interrelationships in planning, design and construction of the large span, single story hangar structure with all the supporting utilities.

The three papers comprising the symposium on the "Kelly Air Force Base Maintenance Hangar" are sub-titled "Planning" by Louis A. Nees, A.M. ASCE, Proceedings Paper 852; "Engineering Design Features" by N.H. Aslanian, A.M. ASCE, Proceedings Paper 853; and "Construction Features" by W. H. Fasshauer, A.M. ASCE, and C. W. Edwards, Proceedings Paper 854.

The first paper of the group describes the basic studies of the Air Force operational and functional requirements. The major feature of interest is in its provision to enable maintenance on a simultaneous "production line" and "stall" basis for all types of aircraft, including the largest bombers (B-36, B-52, and B-47) in operation today. The planning established a facility consisting of a hangar 2,000 ft. long, 300 ft. wide area flanked by a shop structure 250 ft. wide, plus a maintenance type apron of 300,000 square yards. As a result, aircraft can be handled on a production line basis and "staged" in or out of the line depending on the scope of work involved while at the same time the facility supports "stall" type overhauls on the apron.

The second paper of the group covers mostly design, fabrication and method of erection of the principal hangar structure, and also general features of interest, including foundations, apron slabs and all the supporting facilities.

The last paper of the symposium discusses in detail all the construction activities and the execution of the project up to completion. This maintenance hangar facility totalling a record-breaking hangar and shop roof area of 23.4 acres and measuring slightly less than a mile in perimeter will be completely ready for occupancy by mid-February 1956, and will be the world's largest and most modern hangar structure.

The first two papers of the Symposium on "Planning" and "Engineering Design Features", by Messrs. L. A. Nees and N.H. Aslanian, respectively, have been programmed to be presented at the American Society of Civil Engineers' meeting in Dallas, Texas, in February 1956.

Reprints from this publication may be made on condition that the full title of paper, name of author, page reference (or paper number), and date of publication by the Society are given.

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KELLY AIR FORCE BASE MAINTENANCE HANGAR: PLANNING

Louis A. Nees,[1] A. M. ASCE

SYNOPSIS

This Hangar and Shop complex is believed to be the largest in area in the world today. Based upon the production line concept of operations and being the first of this size ever built for maintenance use in the U. S. Air Force its planning and design represented some unusual problems. This paper outlines the basic principles and the steps employed in establishing the size, configurations, and shop layouts. The following papers, one by N. H. Aslanian,[2] A. M. ASCE and the other by Messrs. W. H. Fesshauer,[3] A. M. ASCE and C. W. Edwards,[3] present the design and construction features respectively of the facility.

1. This giant aircraft repair facility which is being constructed for the Air Force at Kelly AFB, San Antonio, Texas, embodies a completely new concept in the overhaul of military aircraft. The structure when completed will consist of a hangar section 300 feet wide and 2,000 feet long providing a clear span of 250 feet and a clear height of 50 feet to the underside of crane hooks. Flanking this is a one-story shop section 250 feet wide and 1,600 feet long with a clear height of 20 feet to the underside of monorail hooks except for a special high-bay section of 30 feet clear height. Administrative and cafeteria space is provided in a second floor portion at the approximate middle of the shop section.

2. Figure 1 shows elevation, typical cross section and floor plan of the development. At first glance the layout and arrangement look deceptively simple. Most laymen and in fact an appreciable number of engineers think that a hangar is merely a giant shell flanked by some shops into which all kinds of aircraft can be indiscriminately stuffed and worked on. Actually the overhaul of modern aircraft is a complex industrial operation which must be carefully planned and designed. The present structure for instance represents the culmination of over two (2) years of intensive planning.

3. Planning an AF facility for the depot overhaul of military aircraft presents quite a different problem from that involved in the design of an aircraft production plant or a commercial airline overhaul facility. In the latter cases the facilities are designed around one or a few specific aircraft and a fixed method of construction and overhaul. Further as aircraft becomes obsolescent and new ones are brought into production and use, the manufacturere and commercial operator are usually in a position to write off the existing fixed plant and invest in new plant or major reconstruction of the old in order to accommodate the new type aircraft.

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1. Chief, Engr. Branch, Installations Div., Hq. AMC, Wright-Patterson Air Force Base, Ohio.
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4. The problems in a military aircraft overhaul plant are uniquely different. In the first place, since new plant is financed by appropriation from Congress, it must be placed into a budget program (and basically planned) at least 3-1/2 years prior to the time initial use is anticipated. Secondly, in view of the necessity of obtaining Military Construction funds for new facilities or major rework of such facilities it is necessary to plan for the utmost flexibility and adaptability to meet the requirements of future aircraft. This means the necessity for forecasting aircraft develo pment trends as much as 10-15 years away - an almost impossible feat in this fast moving technology.

5. As if this were not enough, the constantly changing concepts of global defense cause periodic changes in the mission of the overhaul depots in the AMC and the planner of the facility must therefore also consider its adaptability for overhauling many different types of aircraft from fighters through cargo aircraft to bombers.

6. One of the first steps in planning was to determine the basic cross-sectional area of the hangar. A study was first made of the configuration of the various types of aircraft in production and in development for the AF. Efforts were also made to ascertain the configuration and dimension trends which might be expected in large aircraft in the foreseeable future.

7. Kelly AFB is a depot whose principal function in aircraft repair is centered on large piston-engined cargo and bomber aircraft both piston and jet-engined. Therefore, the facility must be basically planned for this requirement. Under the AMC maintenance concept a depot such as Kelly becomes responsible not only for the Depot overhaul of certain types of aircraft as required at fixed periods by regulations but also for the support of all such aircraft types operating within a prescribed region by performing emergency repairs, overhaul and modifications as required.

8. When an aircraft toes in for a depot overhaul it is dismantled under a progressive system known as IRAN (Inspect and Repair as Necessary). The phrase is self explanatory and while it means a great saving in time and money in the repair of aircraft it also means that basically no two aircraft will ever go through the same repair cycle sequence.

9. The commonly accepted (and still in great use) method of overhauling large aircraft is the "Stall" method in which the aircraft is brought into the hangar and worked on while in a fixed position. This method is particularly adaptable to low-workload-factor overhauls or to operations in which only one or possibly two aircraft are overhauled at a time. However for high-density operations involving many aircraft this plan is not so efficient because of the ineffective use of specialists and longer and crossing paths of the various operations.

10. A study of the Kelly operational requirements indicated that the number and types of aircraft to be overhauled varied so widely and the workload was so great that a structure designed to house all operations would not only become unreasonable from the standpoint of cost but would not take into account the climatic advantages of the locatio n which affords long seasons amenable to working in the open.

11. Further study showed that bypproviding appropriate apron facilities contiguous to the structure a practical operational concept could be developed along the following lines:

a) Pre-overhaul washing, cleaning, defueling and decontamination of the aircraft to be accomplished on the apron.

b) Check-out of the aircraft's systems to be generally accomplished on the apron.

c) Overhaul of smaller or less critical aircraft (from the standpoint of schedules) on the apron and in the smaller stall-type hangars.

d) Overhaul of the larger aircraft such as the B-36, B-52, C-124, C-119, B-50, in the structure.

12. Based on this concept the workload projections indicated a need for overhaul of twelve B-36 type aircraft at one time or 25 aircraft of the B-50 size. The resultant hangar space requirements were 600,000 square feet. The relationship between aircraft workload volume and shop space requirements has been well established by long years of experience so it was not too difficult to extend such relationship to the case in question which pointed to a need for 400,000 square feet of shop space.

13. Studies were then started on the actual configuration. The following types were analysed.

a) Hangar and shop side-by-side (see figure No. 1).

b) Hangar flanking both sides of the shop (see figure No. 2).

c) As above with 2-story shops (see figure No. 3).

d) Circular plan with shops in the inner annular ring (see figure No. 4).

14. It may be of interest to examine the major factors which lef to the final selection.

a) Plan d is one which at first glance would prove economical both from the standpoint of space requirements and construction costs. Actually this is not true. In the first place, it was found that while the 12 large planes could be accommodated in 1,060,000 square feet compared to the 1,100,000 square feet in rectangular plans, the added costs of framing and utilities in the circular plan increased the costs to the point where no savings were indicated. More important however were the operational drawbacks such as wasted space in the hangar section, poor efficiency from the 2 story shop arrangement, the impracticability of full length crane service in the hangar, the necessity for blocking the hangar line by personnel and vehicle crossings and the increased fire hazard as a result of containing the shops in the inner area.

b) Plan b possesses the advantage of lower first cost by offering possible savings in construction. Furthermore it offers apparent advantages in operation by providing short and flexible means of communication between individual shops and aircraft. Its principal disadvantages are decreased operational effectiveness due to turn-around of the aircraft, an increased fire hazard and a more complex and inefficient shop arrangement due to the necessity for providing a wider shop and the generation of traffic through shop areas.

c) Plan c possesses compactness and a reduced cost per square foot of total area. However the operational efficiency is reduced and an increased fire hazard is involved. The 2nd story shop area with the necessity for vertical travel of parts, people and equipment did not yield an efficient shop arrangement. Many of the people involved in the planning favored this basic arrangement and some of the variations in ideas contemplated elevators and even truck ramps and passages on the 2nd floor shops. All such ideas however did not overcome the disadvantages stated above.

d) Scheme a which was finally adopted for the design has the advantage of lowest first cost coupled with short effective lines of communications between shops and aircraft.l Further it permits maximum future expansion of both hangars and shops: it offers maximum flexibility in introducing aircraft into any stage of the "line" or taking it out; and it permits the shops to give effective support to the apron activities.

15. Concurrent studies on dimensional requirements indicated that all present and programmed type of aircraft could be handled within a range of 240 feet. There appeared to be a natural grouping into the following sizes: 230 feet, 120 feet, and 70 feet. Experience has shown that large aircraft of the 230 feet class can be effectively positioned within 5 feet each side of the desired centerline position without much difficulty. This tolerance plus working allowance around wing edges dictated the use of the 250 ft. clear width. Studies with cutout models indicated that 250 ft. width was necessary to get large aircraft turned out or into the line through the side doors. This not only provides for future probable increased wing spans but lends itself well to the establishment of double and triple lines for smaller aircraft. Studies of tail lights indicated that a clear height of 50 ft. under the crane hooks (60 ft. to underside of truss) would handle all present aircraft with reasonable allowance for future ones.

16. Since the aircraft must be capable of entering and leaving the hangar through the side doors the basic hangar module becomes 300 x 250 feet, which makes allowances for space taken up by the main trusses.

17. Under the concepts described in preceding paragraphs the overhaul cycle for, let us say a large bomber is as follows:

a) Removal of fuels and lubricants.
b) Decontamination, purging and general cleaning.
c) Inspection and check out of systems as follows'
    1) Fire control
    2) Navigation
    3) Communications
    4) Power Plants
    5) Air Frame and Control Surfaces
    6) Fueling
    7) Landing Gears
    8) Miscellaneous (fire protection, lights, batteries, etc.)
d) Repair and/or replacements of systems or components thereof.
e) Final Inspection.
f) Weigh and balance.
g) Flight testing.

18. Category a work is performed at special stations on adjacent aprons. Here all fuels are removed, power plants are drained and excess lubricants and hydraulic fluids are removed.

Category b work is also performed on an apron station, many times at the same place as for (a) work. Here the fuel tanks and systems are purged of explosive vapors and the fuel tanks are treated to prevent deterioration. The aircraft is also thoroughly washed of all grease and dirt and if necessary decontaminated of any radioactive matter it may have on it.

Concurrently with the above, category c work has been underway and as the aircraft comes off the washing station to enter the hangar inspectors for the various systems swarm over it to complete their portions of the shop order for the aircraft by the time it enters the shop. By the time the aircraft enters the first station in the shop the inspection has been completed, the shop order written and the craft is ready for the mechanics.

The next category of work (d) goes on in the hangar and it largely determines the plant flow and equipment layout. Figure No. 5 shows the plant layout as finally adopted. Under the IRAN system and the responsibility for area

support each aircraft requires a type and extent of overhaul which may and generally is completely different from the one preceding or following it. For instance one aircraft may be found to require almost complete replacement of the fire control system, major work on the control surfaces and just some prescribed modification in the navigation system. Another aircraft on the other hand may require replacement of all power plants, complete replacement of the fueling system and major work on the landing gear system. All sorts of variations occur and their net effect is that there is no reliable method of determining prior to actual inspection how much time the aircraft must spend in any one station.

In drawing upon past records and experience it however became apparent that practically every aircraft needed some work done on the power plant involving its removal. It was also indicated that wing members, airframe members or parts of the surface needed some work involving removal of parts. Since both these jobs involved the handling of large-size pieces a high bay area for each is required. Trends in engines and the sizes of airframe components indicated a need for 30 feet clear height.

At first glance it might appear logical to care for these areas opposite the first station since they might be most nearly termed a common operation. However the preparatory work required for dismantling, the time involved in repair or replacement, the variation in repair sequence for aircraft showed that the most economical position for these facilities was near the middle of the hangar.

Our repair experience shows that in addition to the general cleaning which has been given to the aircraft, additional cleaning is needed for the smaller surfaces and component parts, and for landing gear components. Since this work in a sense tends to disrupt the normal cycle and since it employs flammable solvents, the logical place for it was at that end of the shop contiguous to the entrance end of the hangar.

The next operation is to overhaul the airframe and wing sections. This is also an operation requiring high bay area. Functionally it was found that the time required for airframe and engine overhaul would not permit completion of the airframe work while the aircraft was in its first position. In fact the studies showed that these operations would generally involve all the aircraft in the first 1,000 feet of the hangar. Since the control on all supporting operations of the Airframe Section (fabric, plexiglass and sheet metal repair, paint and dope work, tank sealing, etc.) is functionally exerted at one point it was found both operationally practical and economical to place the high bay portion for this function adjacent to and in front of the engine section and to place the supporting shops previously noted in front of this.

Somewhere in the shop complex, space is required for other functions which for reasons of security, nature of process, or fire hazards require special enclosures. These are such items as cordage space, battery shop, instrument check and test space, classified instrument shops and storage. AF policy further required that some or all of these spaces be protected by fire walls. After a study of various space arrangements it soon became evident that there was only one effective and economical compromise that could be made if the maximum amount of shop space was to be kept flexible. This was to group all such operations in the middle of the hangar between fire walls. As seen in figure No. 5, this not only enabled us to include such features as Technical Order files and dispenseries, but also afforded economical development of the office and cafeteria space above.

The arrangement of the remaining space then rapidly lent itself to orderly assignment. First the area required for project material which furnishes the

stock backup for so much of the work involved in the electrical armament and instrument shops must be close to such operations but should not use space adjacent to the hangar. This fixed the location in the far outer corner of the shop area as indicated.

The next key feature is the landing gear section which should be as close to the middle as possible since the work must be definitely completed before the aircraft get too close to the end of the line. This also dictated that the hydraulic test section should follow immediately behind it.

Armament, radar and electrical are closely related with the latter in what might be called a support category. It then becomes a sort of Hobson choice as to where to locate them. It was decided that since parts routing in and out of project material storage is common to all these functions that this section might better be placed near the end as shown.o Armament was placed adjacent to the hangar and behind the hydrostatic test section because of the greater weight of the items involved and because in a considerable number of cases the armament might not involve electrical work.

There was not much choice therefore as to where to place the electrical section except where shown.

The final space exclusive of the rest room was then assigned to the final inspection office where the work order is checked for compliance. From there the aircraft is weighed and balanced and is then towed out on the apron to be readied for its flight test.

The shop arrangement as you readily may perceive is full of compromises and therefore may possibly be critized from the standp oint that alternate workable solutions may exist. However the one adopted was the result of bringing to bear on the problem the combined thinking of many people with a great deal of aircraft overhaul experience. We are however completely sure of one thing; that irrespective of the arrangement adopted the fast moving development in the aircraft field will require us to revise our arrangements before too many years have elapsed.

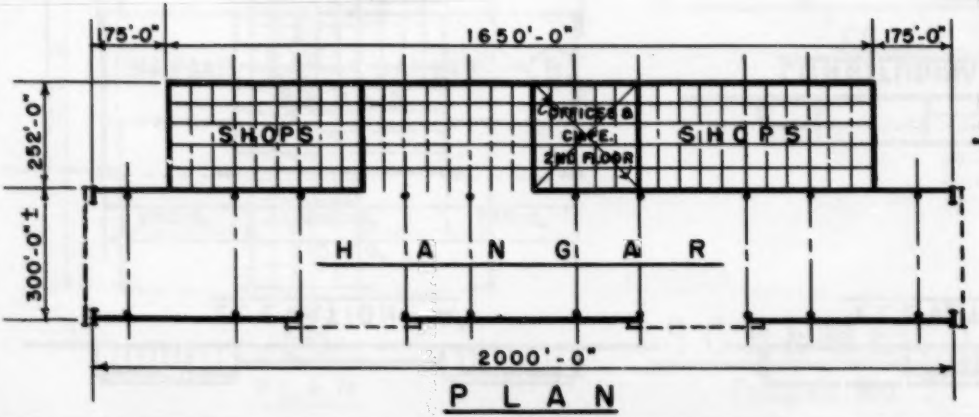
The major work in the operational planning of the structure was carried out by the Maintenance Plans Branch of the Maintenance Engineering Directorate, Hq AMC, under the supervision of Messrs. H. W. Kling and H. F. Fetter assisted by representatives of the Maintenance Engineering Directorate of Kelly AFB. Coordinati n of the structural phases was carried out in the Installations Division, Hq AMC under the supervision of the writer and under the direction of Colonel E. C. Gill, USAF, Chief of the Division.

SIDE ELEVATION

CROSS SECTION

HANGAR ELEVATION

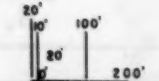
SQ. FT. SHOPS + 2ND FLOOR - 500,000±
SQ. FT. HANGAR - 600,000
TOTAL SQ. FT. - 1,100,000±



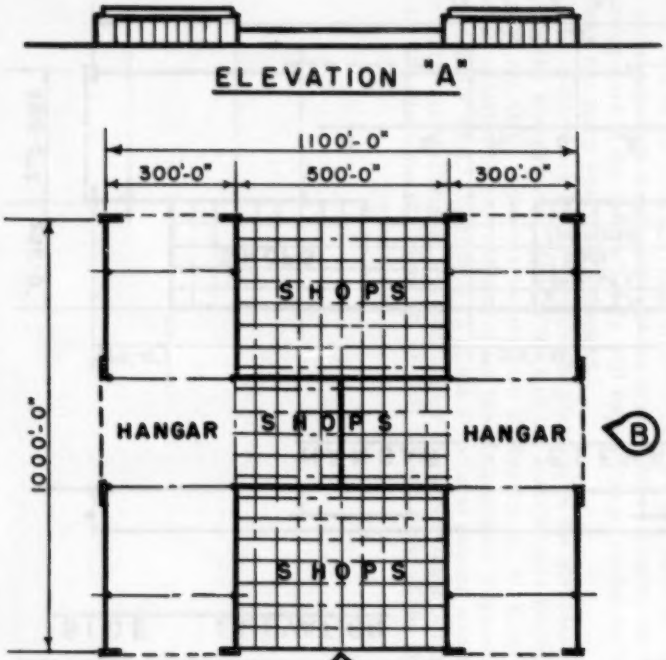
PLAN

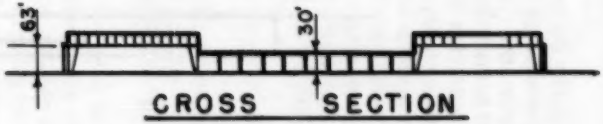
SCHEME "A"

FIGURE NO. 1

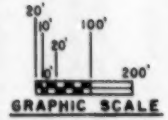


GRAPHIC SCALE





SQ. FT. SHOPS - 500,000
SQ. FT. HANGAR - 600,000
TOTAL SQ. FT. - 1,100,000

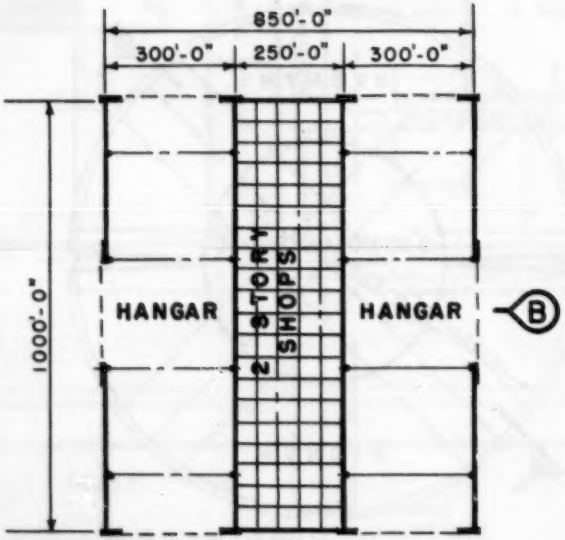


SCHEME "B" FIGURE NO. 2

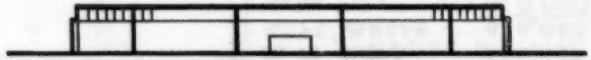
852-8

ELEVATION "A"

ELEVATION "B"



PLAN



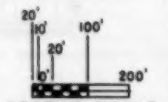
LONGITUDINAL SECTION

CROSS SECTION

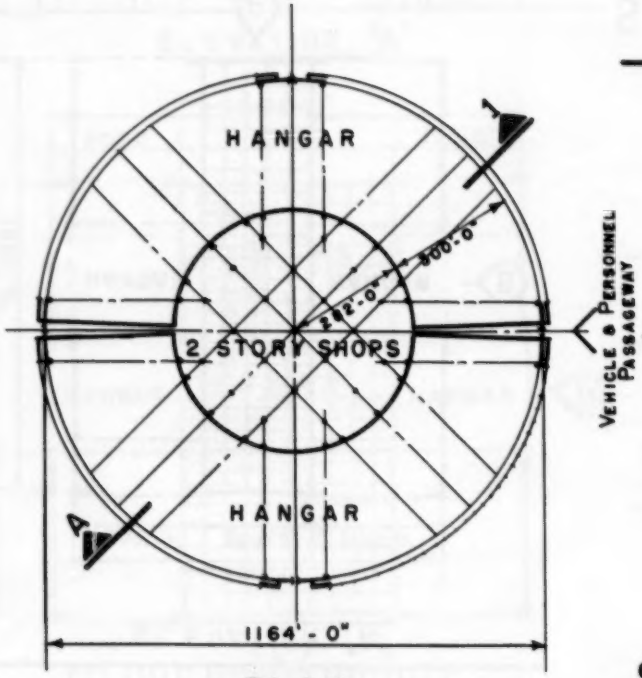
SQ. FT. SHOPS	-	500,000
SQ. FT. HANGAR	-	600,000
TOTAL SQ. FT.	-	1,100,000

SCHEME "C"

FIGURE NO. 3

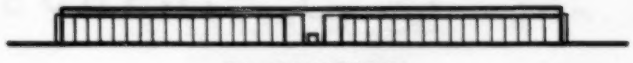


GRAPHIC SCALE



PLAN

VEHICLE & PERSONNEL PASSAGEWAY



ELEVATION

CROSS SECTION A1

SQ. FT. SHOPS	-	500,000
SQ. FT. HANGAR	-	810,000
TOTAL SQ. FT.	-	1,310,000

SCHEME "D"

FIGURE NO. 4

GRAPHIC SCALE

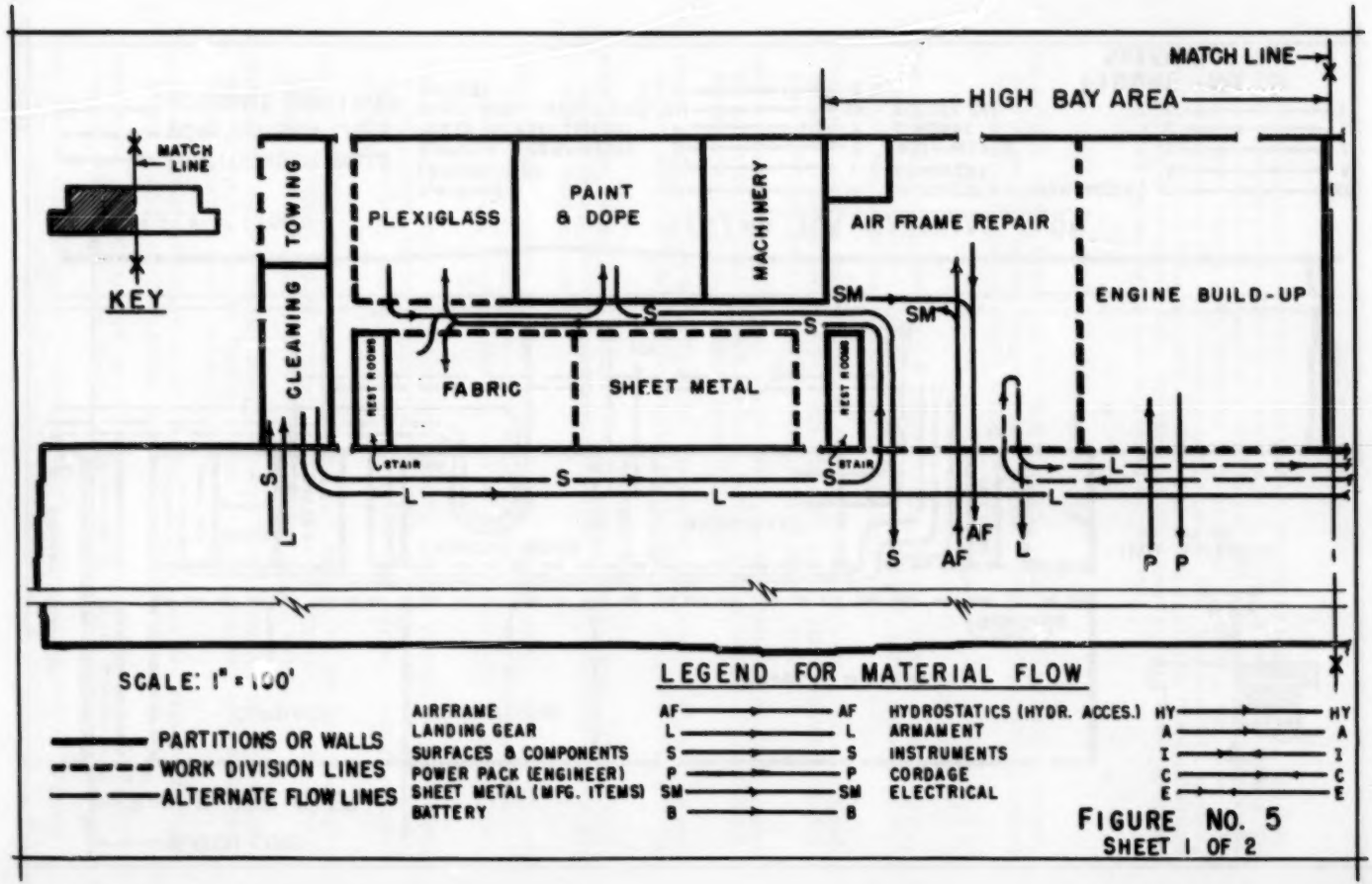


FIGURE NO. 5
SHEET 1 OF 2

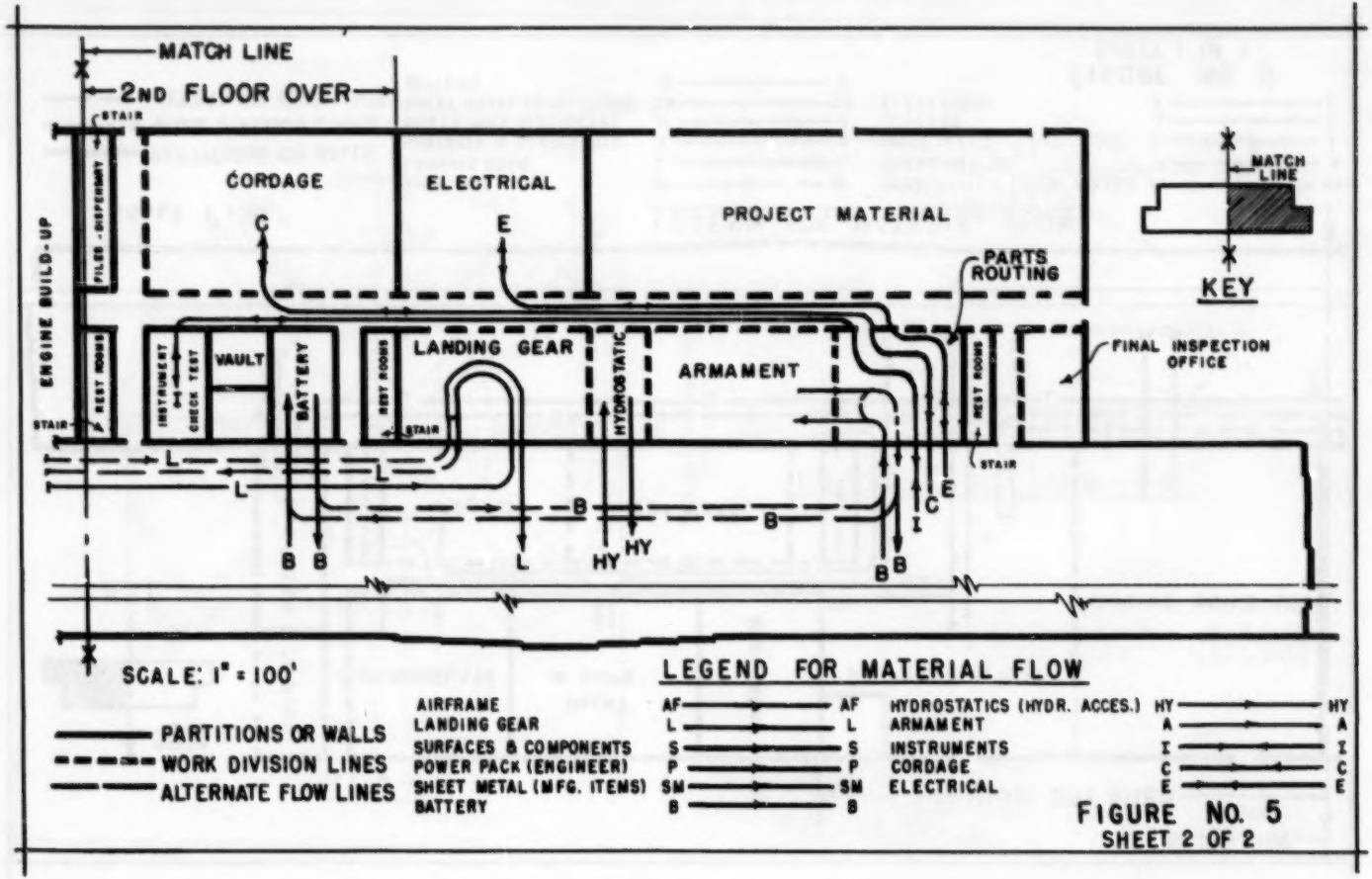


FIGURE NO. 5
SHEET 2 OF 2

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

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DECEMBER: 558(ST), 559(ST), 560(ST), 561(ST), 562(ST), 563(ST)[c], 564(HY), 565(HY), 566(HY), 567(HY), 568(HY)[c], 569(SM), 570(SM), 571(SM), 572(SM)[c], 573(SM)[c], 574(SU), 575(SU), 576(SU), 577(SU), 578(HY), 579(ST), 580(SU), 581(SU), 582(BD).

VOLUME 81 (1955)

JANUARY: 583(ST), 584(ST), 585(ST), 586(ST), 587(ST), 588(ST), 589(ST)[c], 590(SA), 591(SA), 592(SA), 593(SA), 594(SA), 595(SA)[c], 596(HW), 597(HW), 598(HW)[c], 599(CP), 600(CP), 601(CP), 602(CP), 603(CP), 604(EM), 605(EM), 606(EM)[c], 607(EM).

FEBRUARY: 608(WW), 609(WW), 610(WW), 611(WW), 612(WW), 613(WW), 614(WW), 615(WW), 616(WW), 617(IR), 618(IR), 619(IR), 620(IR), 621(IR)[c], 622(IR), 623(IR), 624(HY)[c], 625(HY), 626(HY), 627(HY), 628(HY), 629(HY), 630(HY), 631(HY), 632(CO), 633(CO).

MARCH: 634(PO), 635(PO), 636(PO), 637(PO), 638(PO), 639(PO), 640(PO), 641(PO)[c], 642(SA), 643(SA), 644(SA), 645(SA), 646(SA), 647(SA)[c], 648(ST), 649(ST), 650(ST), 651(ST), 652(ST), 653(ST), 654(ST)[c], 655(SA), 656(SM)[c], 657(SM)[c], 658(SM)[c].

APRIL: 659(ST), 660(ST), 661(ST)[c], 662(ST), 663(ST), 664(ST)[c], 665(HY)[c], 666(HY), 667(HY), 668(HY), 669(HY), 670(EM), 671(EM), 672(EM), 673(EM), 674(EM), 675(EM), 676(EM), 677(EM), 678(HY).

MAY: 679(ST), 680(ST), 681(ST), 682(ST)[c], 683(ST), 684(ST), 685(SA), 686(SA), 687(SA), 688(SA), 689(SA)[c], 690(EM), 691(EM), 692(EM), 693(EM), 694(EM), 695(EM), 696(PO), 697(PO), 698(SA), 699(PO)[c], 700(PO), 701(ST)[c].

JUNE: 702(HW), 703(HW), 704(HW)[c], 705(IR), 706(IR), 707(IR), 708(IR), 709(HY)[c], 710(CP), 711(CP), 712(CP), 713(CP)[c], 714(HY), 715(HY), 716(HY), 717(HY), 718(SM)[c], 719(HY)[c], 720(AT), 721(AT), 722(SU), 723(WW), 724(WW), 725(WW), 726(WW)[c], 727(WW), 728(IR), 729(IR), 730(SU)[c], 731(SU).

JULY: 732(ST), 733(ST), 734(ST), 735(ST), 736(ST), 737(PO), 738(PO), 739(PO), 740(PO), 741(PO), 742(PO), 743(HY), 744(HY), 745(HY), 746(HY), 747(HY), 748(HY)[c], 749(SA), 750(SA), 751(SA), 752(SA)[c], 753(SM), 754(SM), 755(SM), 756(SM), 757(SM), 758(CO)[c], 759(SM)[c], 760(WW)[c].

AUGUST: 761(BD), 762(ST), 763(ST), 764(ST), 765(ST)[c], 766(CP), 767(CP), 768(CP), 769(CP), 770(CP), 771(EM), 772(EM), 773(SA), 774(EM), 775(EM), 776(EM)[c], 777(AT), 778(AT), 779(SA), 780(SA), 781(SA), 782(SA)[c], 783(HW), 784(HW), 785(CP), 786(ST).

SEPTEMBER: 787(PO), 788(IR), 789(HY), 790(HY), 791(HY), 792(HY), 793(HY), 794(HY)[c], 795(EM), 796(EM), 797(EM), 798(EM), 799(EM)[c], 800(WW), 801(WW), 802(WW), 803(WW), 804(WW), 805(WW), 806(HY), 807(PO)[c], 808(IR)[c].

OCTOBER: 809(ST), 810(HW)[c], 811(ST), 812(ST)[c], 813(ST)[c], 814(EM), 815(EM), 816(EM), 817(EM), 818(EM), 819(EM)[c], 820(SA), 821(SA), 822(SA)[c], 823(HW), 824(HW).

NOVEMBER: 825(ST), 826(HY), 827(ST), 828(ST), 829(ST), 830(ST), 831(ST)[c], 832(CP), 833(CP), 834(CP), 835(CP)[c], 836(HY), 837(HY), 838(HY), 839(HY), 840(HY), 841(HY)[c].

DECEMBER: 842(SM), 843(SM)[c], 844(SU), 845(SU)[c], 846(SA), 847(SA), 848(SA)[c], 849(ST)[c], 850(ST), 851(ST), 852(ST), 853(ST), 854(CO), 855(CO), 856(CO)[c], 857(SU), 858(BD), 859(BD), 860(BD).

c. Discussion of several papers, grouped by Divisions.

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